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Timber-frame facade elements for hybrid construction

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Summary

In the interdisciplinary research project three chairs of TUM (Chair of Timber Structures and Buildung Construction, of Energy Efficient and Sustainable Design and Building and of Concrete and Masonry Structures) as well as Ift Rosenheim (Department of Building Acoustics) are working together. The symbiosis between timber-frame elements and solid structure is being developed considering the state-of-the-art with regard to all relevant aspects of structural design and building physics including heat, moisture, sound and fire protection. Additionally, the field of increasing emphasis, life cycle analysis and recyclability of materials used in construction is included by considering certain carbon footprint values etc.
The outcome is a construction catalogue for hybrid construction including standardized elements and details with technical and legal feasibility.

Keywords: Carbon Footprint, Construction catalogue, Recyclability, Reinforced concrete structures, Timber-frame façade elements

1 Introduction

In multi-storey buildings very efficient and well-proven structural work solutions are offered by reinforced concrete frame and bulkhead constructions, while non-load bearing external walls with high quality can be provided using prefabricated timber-frame facade elements. Nevertheless, in Germany such façade elements are rarely used in new reinforced concrete, steel or composite constructions.
Against the background of the significantly increased degree of industrialization of timber construction companies, a greater cooperation between the classical construction sector and timber construction companies should be expected in future.
Due to certain application technologies, prefabricated timber-frame elements allow delivering to the building site highly insulated elements including glazing and appliqued facade elements. Consequently, the time of building constructions can considerably be reduced in total.
The evaluation of different projects has shown that combining different construction methods offers a great potential for further industrialization and acceleration during construction processes in combination with an increase of quality standards and an improvement of working conditions. Knowledge gaps in the field of sound insulation, fire protection and deformation compatibility as well as the lack of information of consistent and coordinated construction details are considered and included in the project.
The execution of well-designed and defect-free constructions has an important part to play in influencing sustainability. In order to achieve the climate protection targets, the energy and resource efficiency of new buildings have to be improved during pre-fabrication and erection, including the essential part of the optimization of building skins.

Furthermore, comprehensive systematic descriptions of application possibilities are compiled, for example residential, office or school constructions. In case of residential and office buildings, the timber-frame facade elements can be used up to the limit of high-rise buildings (≤ eight storeys).

In parallel, experiences gained during the process of research-supporting projects (e.g. construction project "Städtischer Hartplatz" in Penzberg) give an insight of the practicability of hybrid constructions and provide helpful results for the elaboration of the construction catalogue.

2 Integrative planning process

During the entire construction process - including the design of the structure and the building progress - the basic, preliminary and conceptual planning phase imply the decisive phase. Here, problem-solving processes of pre-planning are already included and determine the following phases. During this decisive phase, costs, time and quality are essentially determined.

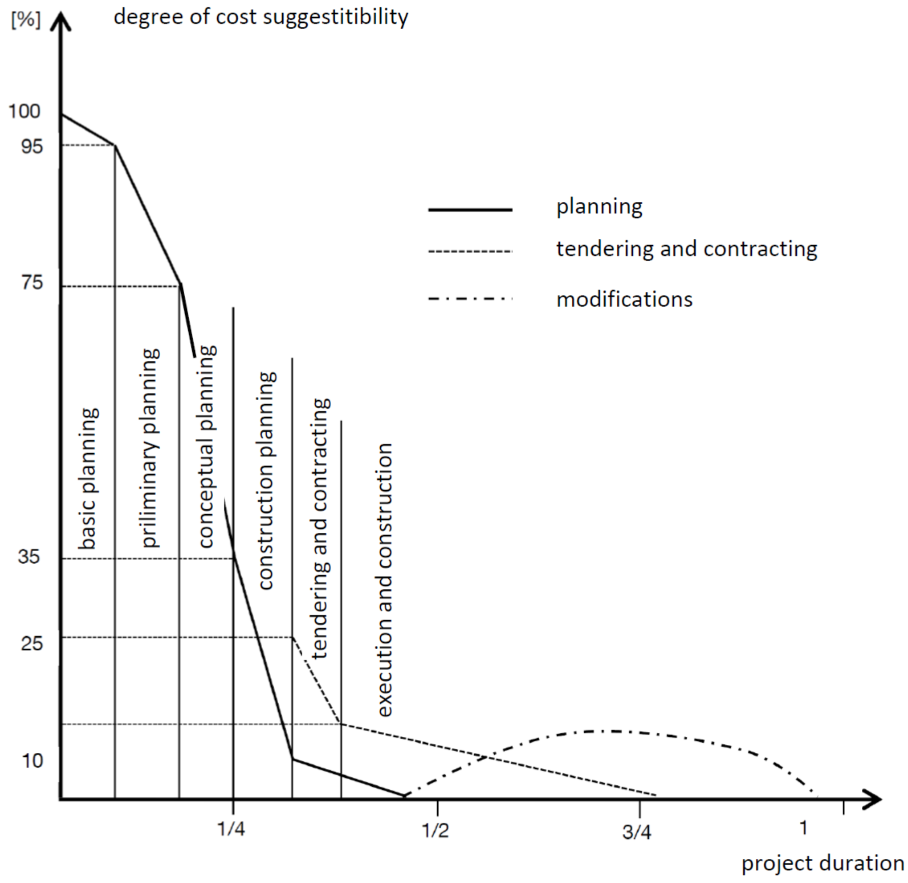


Figure 1: Dependence of cost sugesstibility in the construction phase,
taken from [1] in modified form

Economic and time constraints can only be complied, if the procedure of pre-fabrication and erection are also considered in the planning phase. Already in the early stages of a project, integrative and cooperative planning is indispensable for intensive networking between planning and construction processes. This networking is mirrored in the composition of the different chairs and by the support of the project related working group.

3 Identification of hybrid design

The load-bearing structure consists of reinforced concrete elements, e.g. in situ concrete, partly and fully pre-fabricated concrete elements as well as reasonable mixed structures. The design principles can be divided into skeleton and / or bulkhead structures.

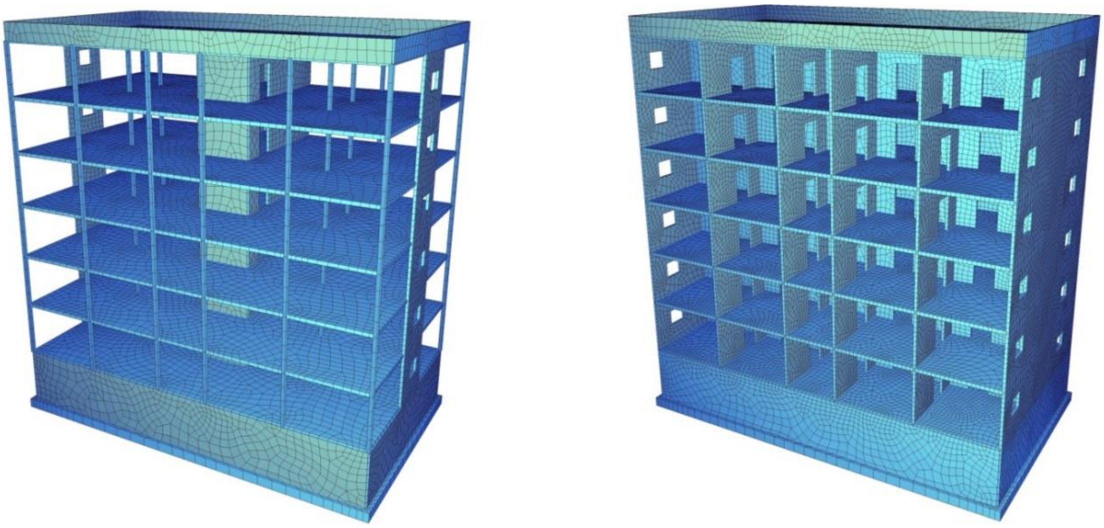


Figure 2: Examples for load-bearing structures in reinforced concrete,
frame structure (left) and bulkhead structure (right)

The non-loadbearing timber-frame elements are fixed to the supporting concrete structure. For non-loadbearing exterior walls a fire resistance of 30 minutes is required in building class 4 and 5. With regard to fire protection, the timber-frame elements should be anchored in each storey. Otherwise the elements have to be classified as load-bearing elements including a fire resistance of 60 minutes in building class 4 and 90 minutes in building class 5. Figure 3 shows the position and fixing possibilities of timber-frame elements related to the concrete structure.

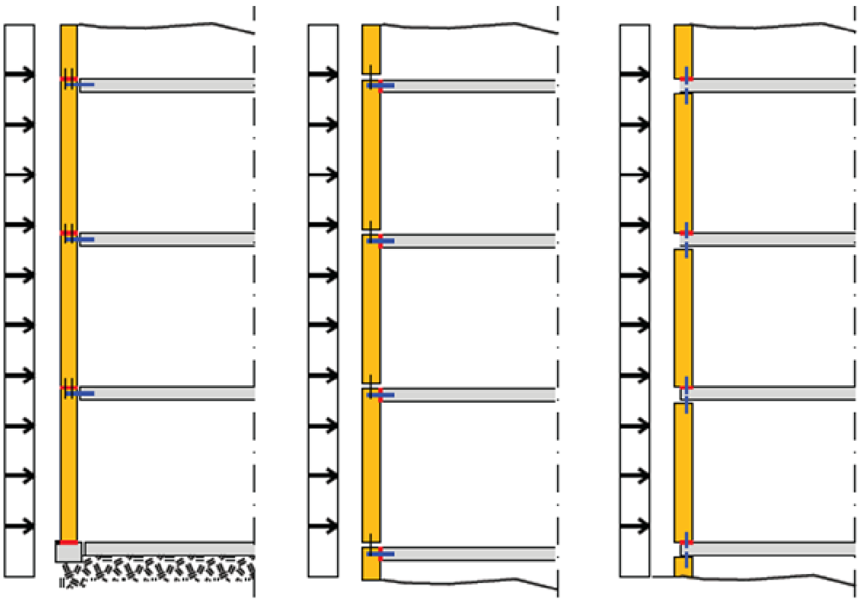


Figure 3: Principles of highly-insulated timber-frame elements related to reinforced concrete structures,
outside supporting below (left) and on top (centre), partly or fully integrated (right)

Taking into account the aspect of the erection and a useful attachment of the prefabricated timber elements, only the exterior walls situated outside (case left) or integrated in the supporting concrete structure (case right) are further included in the construction catalogue.

4 Detailing of timber-frame facade elements

In combination with the load-bearing structure the following issues are to be solved:

a) Mechanical resistance and stability:

- Connections between reinforced concrete and timber-frame assemblies have to be designed most economically.
- In reinforced concrete structures, e.g. floor constructions with spans of 5,50 m to 7,00 m, not only short but also long-term deformations have to be taken into account. These deformations have a great influence on the connection between the timber and the concrete structures. Gaps between floor and exterior wall constructions have to fulfill the requirements related to long-term deformations as well as mounting tolerances.

b) Safety in case of fire:

- The spread of fire through ventilated facade systems, over joints between timber elements and concrete structure has to be prevented.

c) Energy economy and heat retention:

- For the defined connections a complete catalog of thermal bridges will be provided.

d) Protection against noise:

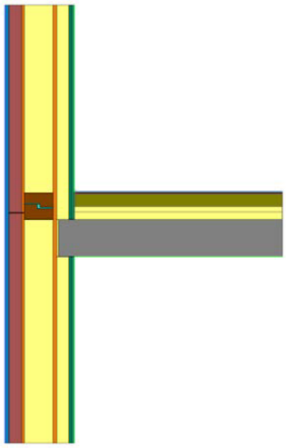
- Values of flanking transmission of structure-borne and impact sound will be measured in laboratory and building site including also constructions with increased noise protection.

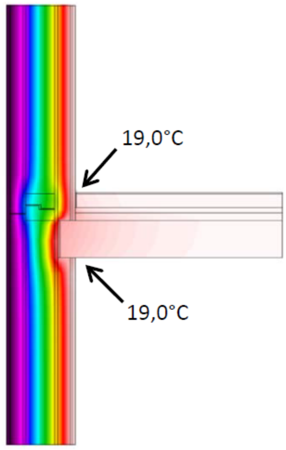
e) Sustainable use of natural resources

- In the context of contract decision and certification systems the life cycle analysis (LCA) and recyclability of used assemblies becomes increasingly important. Therefore it is necessary to provide CO_2-equivalents etc. for the timber-frame assemblies.

Figure 4 shows for example the thermal bridge coefficient of a connection between reinforced concrete floor and external wall ($U = 0{,}15\ Wm^{-2}K^{-1}$).

BA7a	Anschluss Außenwand - Decke - Außenwand
Randbe-dingungen:	Randdämmstreifen mit WLS 040



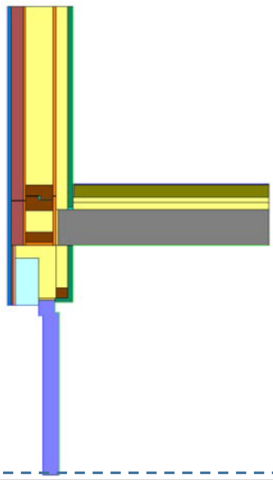


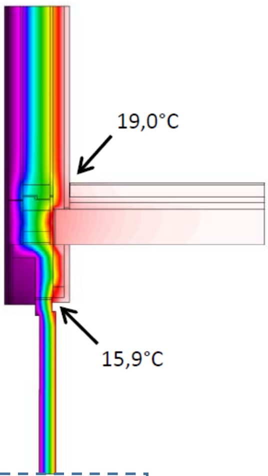
Wärmebrückenkoeffizient Ψe (außenmaßbezogen)	0,032 W/mK	f_{Rsi}	0,96 oben 0,96 unten

Figure 4: Connection of reinforced concrete floor with timber frame elements

Figure 5 shows the influence of thermal bridge coefficient of the same connection including a window.

BA7g	Anschluss Roka-Shadow - Decke - Außenwand
Randbe-dingungen:	Randdämmstreifen mit WLS 040, Außenmaßbezug auf Rohbaumaß des Fensters





Wärmebrückenkoeffizient Ψe (außenmaßbezogen)	0,085 W/mK	f_{Rsi}	0,96 oben 0,84 unten

Figure 5: Connection of reinforced concrete slab with timber frame elements including a window

The details were developed in a workshop with the project-supporting working group. The range of thermal bridge coefficients will be specified in parametric studies.

5 Project-related example

The fact of the growing importance of environmental issues - particularly in the construction industry - is leading to an increased demand for sustainably constructed buildings and neighborhoods with investors, builders and users. Sustainable construction is also worthwhile in economic terms, because this is the major impulse for the development of a master plan. With the construction project "Städtischer Hartplatz" in Penzberg (Germany) initiated by Krämmel GmbH & Co. KG an innovative and sustainable residential development shall be created. The complex consists of ten terraced houses (basement + II + attic), three point houses (basement + II + attic) and two apartment buildings in row construction (basement + III + attic).
Primary objectives will be the improvement of ecological and economic conditions, recoverability and quality of the buildings. There will be different sustainable criteria taken into account, which generate the following additional benefit:

- High comfort
- High user acceptance
- Low operating, maintenance and repair costs
- Sustainable buildings
- Positive public perception
- Good marketing of the object
- High economic output

Figure 6: 3D-visualisation (planning alliance „Städtischer Hartplatz“:
Krämmel Bauplan GmbH und Lang Hugger Rampp GmbH)

The aim of the project "Städtischer Hartplatz" is the development of an integral overall concept by creating a residential neighbourhood in low-energy standard (KfW-efficiency 55 house standard according to Energieeinsparverordnung 2014) and by using ecological materials as well as low-tech solutions. For achieving these goals the following three components has to be considered:
- Grey energy
- Passive energy system

- Energy supply

The interdisciplinary team of the Technische Universität München on the one hand and the long-standing expertise of the construction company in project realization on the other hand can include the different topics with a wider range.

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7 References

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